

Smiljanic 2000-0230

IN THE CLAIMS:

1. **(Currently Amended)** A method of allocating bandwidth for use at a packet switch having a plurality of inputs and a plurality of outputs for switching to specified ones of said outputs, and a plurality of corresponding input buffers having input-output queues, and associated counters, said method comprising the steps of

dividing time into a plurality of frames of time slots, each frame having a specified integer value of time slots;

loading said counters associated with said input-output queues to said a negotiated integer value once per said frame;

said inputs sequentially selecting ~~available~~ said outputs that are available to which said inputs send packets in specified future time slots, wherein priority is given to those of input-output queues whose associated ones of said counters have positive values;

said selection of outputs by said inputs being done by using a pipeline technique where input i , $i = 0, 1, \dots, N - 1$ chooses output for time slot k in time slot $k - \lceil (N - i) / p \rceil$, where p is the number of selections made in one time slot, N is the number of inputs of said switch, and $\lceil (N - i) / p \rceil$ is the smallest integer greater or equal to $\lceil (N - i) / p \rceil$, and

wherein a schedule is calculated within multiple time slots, wherein schedules for multiple future time slots being calculated in each time slot; and

decrementing said counters of selected queues by 1.

2. **(Currently Amended)** A method of allocating bandwidth in a circuit switch having a plurality of inputs for switching to outputs, input tables and input-output counters, said method comprising the steps of:

dividing time into a plurality of ~~(data)~~ data frames comprising ~~(data)~~ data time slots, and reservation frames comprising reservation time slots, each data frame having a specified number of data time slots;

loading said counters to ~~the~~ a difference between ~~the~~ a current total number of negotiated credits and ~~the~~ a total number of released credits in a previous reservation frames of said reservation ~~frames~~ frame;

Smiljanic 2000-0230

said inputs sequentially releasing time slot reservations for outputs if ~~their~~ said inputs corresponding counters have negative values;

said inputs sequentially reserving time slots for unreserved outputs if ~~their~~ said inputs corresponding counters have positive values;

whenever ~~said input~~ one of said inputs releases an output, the corresponding counter is incremented by 1, and whenever ~~said input~~ one of said inputs releases reserves an output the corresponding counter is decremented by 1;

said input tables being updated after all inputs have had a chance to release and reserve outputs for future time slots, storing outputs reserved in each time slot of a frame, and outputs reserved by the corresponding input in each time slot of a frame; and

said releasing of time slot reservations, reserving of time slots, and ~~table update of outputs by said inputs~~ said updating of input tables being done using a pipeline technique, wherein a schedule is calculated within multiple reservation time slots, and schedules for multiple future time slots are calculated in each reservation time slot.

3. (Canceled).

4. (Currently Amended) The method of claim 1, comprising a pipeline technique where input i , $i=0,1,\dots,N-1$, chooses an output from a group of outputs l , $l=0,1,\dots,p-1$, $l=0,1,\dots,N-1$, for time slot k in time slot $k-((N-i)*p-l)$, where p is the number of time slots required for one selection and N is an integer corresponding to the number of inputs of the switch and also to the number of outputs of the switch.

5. (Currently Amended) The method of claim 2, comprising a pipeline technique where input i releases output for time slot $k+mF$, $m=1,2,\dots$ in time slot $\lceil k-(2N-i)/p \rceil$, and input i chooses output for time slot $k+mF$, $m=1,2,\dots$ in time slot $\lceil k-(N-i)/p \rceil$, where $\lceil k-(N-i)/p \rceil$ is the smallest integer greater or equal to $k-(N-i)/p$, and p is the integer ratio of the time slot duration and the reservation time slot duration, F is an integer corresponding to the number of time slots in said frame, and $\lceil x \rceil$ is the smallest integer greater or equal to x .

Smiljanic 2000-0230

6. (Currently Amended) The method of claim 2, comprising a pipeline technique where input i , $i=0,1, \dots, N-1$ releases an output from group of outputs l , $l=0,1,\dots,p-1$ $l=0,1,\dots,N-1$, for time slot $k+mF$, $m=1,2,\dots$ in time slot $k-((N-i)*p-l)-Np$, and input i chooses an output from group of outputs l for time slot $k+mF$, $m=1,2,\dots$ in time slot $k-((N-i)*p-l)$, where p is the ratio of the durations of the reservation time slot and (data) data time slot, and F is an integer corresponding to the number of time slots in said frame.

7. (Original) The method of claim 2, comprising a pipeline technique wherein input table i is finally updated N reservation time slots after it reserved the output.

8. (Currently Amended) The method of claims 3 1 or 5, wherein input i loads its counters in time slot $k * F + 1 - \lceil (N-i) / p \rceil$, where F is an integer corresponding to the number of time slots in said frame.

9. (Currently Amended) The method of claims 4 or 6, wherein input i loads its counters for group of outputs l in time slot $k * F + 1 - ((N-i) * p - l)$, where F is an integer corresponding to the number of time slots in said frame.

10. (Currently Amended) The method of claim 2, comprising a pipeline technique where input i releases output for time slot $k+nF+mpF$, $k < F$, $m, n=1,2,\dots$ in reservation time slot $(m-1)F+k-(2N-i)$, and input i chooses output for time slot $k+nF+mpF$, $m, n=1,2,\dots$ in reservation time slot $(m-1)F+k-(N-i)$ where p is the integer ratio of the reservation time slot duration and the time slot duration, and F is an integer corresponding to the number of time slots in said frame.

11. (Original) The method of claim 10, wherein input i loads its counters in reservation time slot $(m-1)F+1-(2N-i)$.

Smiljanic 2000-0230

12. (Previously Presented) The method of claim 1 or 2 further comprising the step of negotiating values of time slots per frame associated with input-output pairs, wherein input-output pair (i,j) can be allocated additional Δa_{ij} time slots per frame of length F if it holds that:

$$\sum_m a_{im} + \sum_m a_{mj} - a_{ij} + \Delta a_{ij} \leq F,$$

where a_{kl} , $0 \leq k, l \leq N-1$, is the number of time slots previously assigned to input-output pair (k,l) , and N is the number of inputs and outputs.

13. (Previously Presented) The method of claim 1 or 2 further comprising the step of negotiating values of time slots per frame associated with input-output pairs, wherein input-output pair (i,j) can be allocated additional Δa_{ij} time slots per frame of length F if it holds that:

$$\sum_m a_{im} + \Delta a_{ij} \leq (F+1)/2, \quad \sum_m a_{mj} + \Delta a_{ij} \leq (F+1)/2,$$

where a_{kl} , $0 \leq k, l \leq N-1$, is the number of time slots previously assigned to input-output pair (k,l) .

14. (Previously Presented) The method of claim 1 or 2 further comprising the step of updating the number of credits per frame assigned to input-output pair, when its bandwidth request is accepted, or when it releases previously reserved bandwidth:

$$a_{ij} \leftarrow a_{ij} + \Delta a_{ij}.$$

15. (Currently Amended) The method of claim 12 or 13 wherein steps 3 and 4 of bandwidth allocation the claim 1 method are replaced with any maximal matching algorithm, wherein the maximal matching algorithm is ~~the~~ one in which either input will transmit packets or receiver will receive packets in some time slot if there is at least one packet from said input to the said output.

Smiljanic 2000-0230

16. (Currently Amended) The methods of claim[[s]] 12 ~~or 13~~ wherein steps 3 and 4 of the claim 1 method are replaced with the ~~previously proposed~~ parallel iterative matching algorithm (PIM) ~~which is maximal matching algorithm defined in claim 15.~~

17. (Currently Amended) The method of claim 13 ~~wherein applied to the bandwidth allocation in wide area network,~~ wherein switches in a wide area network advertise to other switches reserved bandwidth on all its input and output links:

$$B_i \sum_m a_{im} / F, \quad B_j \sum_m a_{mj} / F, \quad 0 \leq i, j \leq N-1,$$

where B_i, B_j are bit-rates of the corresponding links[[. When]], and when a new bandwidth ΔB is requested between two nodes in the network, then all links for which:

$\Delta B > B_j / 2 - B_i$, are excluded from the network if B_i is the link bit-rate, and B_j is the link reserved bit-rate (bandwidth), and bandwidth is reserved according to any routing protocol (such as OSPF) using remaining links from the source to the destination.

18. (Currently Amended) The method of claim 1 implemented for short packet transmission time T wherein new bandwidth can be allocated fast by using the methods of claims 12 or 13 within time FT even for long frames lengths F , wherein F is an integer corresponding to the number of time slots in said frame and wherein one time slot per frame guarantees bandwidth of B/F by using the methods of claims 12 or 13, where B is the line bit-rate and a minimum guaranteed bandwidth can be made low by increasing F .

19. (Currently Amended) An apparatus for allocating bandwidth for use at a packet switch having a plurality of inputs for switching to specified outputs and a plurality of corresponding input buffers having input-output queues, said buffers being coupled to said input-output queues and having associated counters, said ~~method~~ apparatus comprising the steps of:

time division means for dividing time into a plurality of frames of time slots, each frame having a negotiated integer value of time slots;

Smiljanic 2000-0230

loading means for loading said counters associated with said input-output queues to said negotiated integer value once per said a frame of a preselected number of time slots;
and

means for negotiating values of time slots per frame associated with input-output pairs, wherein input-output pair (i,j) can be allocated additional Δa_{ij} time slots per frame of length F if it holds that:

$$\sum_m a_{im} + \sum_m a_{mj} - a_{ij} + \Delta a_{ij} \leq F,$$

where a_{kl} , $0 \leq k, l \leq N-1$, is the number of time slots previously assigned to input-output pair (k,l), and N is the number of inputs and outputs, and F is an integer corresponding to the number of time slots in said frame;

wherein said inputs sequentially selecting ~~available~~ said outputs that are available to which said inputs send packets in specified future time slots, wherein priority is given to input-output queues with counters having positive values;

and wherein selection of outputs by said inputs is done using a pipeline technique, and wherein not all inputs select outputs for a specified time slot in the future while other inputs choose outputs for some other future time slots.

20. (Canceled) .

21. (Currently Amended) The apparatus of claim 20 19 further including negotiating means for negotiating values of time slots per frame associated with input-output pairs, wherein input-output pair (i,j) can be allocated additional Δa_{ij} time slots per frame of length F if it holds that:

$$\sum_m a_{im} + \Delta a_{ij} \leq (F+1)/2, \quad \sum_m a_{mj} + \Delta a_{ij} \leq (F+1)/2,$$

where a_{kl} , $0 \leq k, l \leq N-1$, is the number of time slots previously assigned to input-output pair (k,l).

22. (Canceled).

Smiljanic 2000-0230

23. (Canceled).